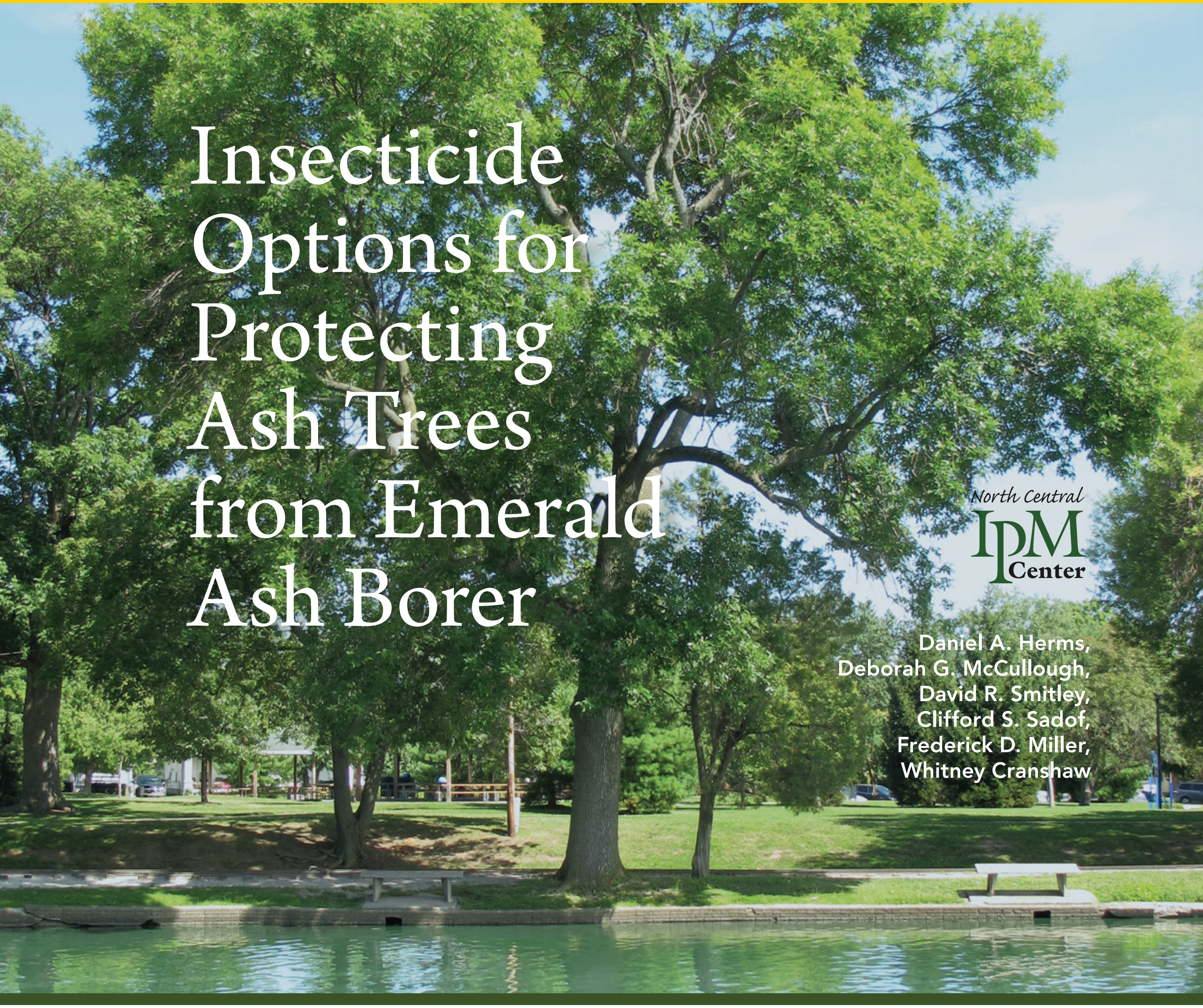
THIRD EDITION



Insecticide Options for Protecting Ash Trees from Emerald Ash Borer

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Contents

Insecticide Options for Protecting Ash Trees from Emerald Ash Borer

Emerald ash borer (*Agrilus planipennis* Fairmaire), an invasive insect native to Asia, has killed untold millions of ash trees (*Fraxinus* species) in urban, rural and forested settings. This beetle was first identified in 2002 in southeast Michigan and Windsor, Ontario. As of December 2018, emerald ash borer (EAB) infestations were known to be present in 35 states as well as five Canadian provinces. Surveys continue and additional infestations will be found as EAB continues to expand its range in North America. Ash trees are common in urban landscapes and residential areas across much of the continental US. Many homeowners, tree care professionals, and municipalities would like to protect valuable ash trees from EAB.

Since EAB was first identified in 2002, our ability to control this pest and effectively protect ash in the landscape has progressed substantially. Scientists have learned much about this insect and how it interacts with its host trees. New insecticide products and application methods have been developed and tested. Results of field trials have shown that ash trees of all sizes can be effectively and consistently protected over multiple years, even in areas with high densities of EAB. Recent economic analyses have concluded that treating landscape ash trees with effective systemic insecticides is much less costly than removing trees.

Our understanding of how EAB can be managed successfully continues to advance. This bulletin addresses frequently asked questions and reflects the current state of knowledge about insecticide options for controlling EAB. It is important to note that research is an ongoing process. Scientists from universities, government agencies and companies will continue to make discoveries to advance EAB management and ash conservation.

Answers to Frequently Asked Questions

What options do I have for treating my ash trees?

Several insecticide options are available to protect landscape ash trees threatened by EAB. Products listed in Table 1 have been evaluated by university and government scientists in field trials. Keep in mind, however, that controlling insects that feed under the bark with insecticides has always been challenging. This is especially true with EAB because most of our native North American ash trees have little natural resistance to this pest. Effective control of EAB requires that the insecticide product applied with the proper method and at the correct time.

I know my tree is already infested with EAB. Will insecticides still be effective?

It is best to begin using insecticides while ash trees are still relatively healthy. By the time most people notice canopy thinning or dieback, EAB has already caused considerably injury to the vascular system of the tree. An effective insecticide may stop additional damage, but it cannot reverse damage that has already occurred and it takes time for trees to recover. Most insecticides used for EAB control act systemically, meaning that the insecticide is transported within the tree. Therefore, a tree must be healthy enough to move a systemic insecticide up the trunk and into the branches and canopy.

Trees are damaged by EAB larvae feeding under the bark in "tunnels" called galleries. Galleries injure the inner bark, called phloem, which affects the transport of nutrients within the tree. The galleries also score or "etch" the outer wood, called xylem, affecting the ability of the tree to transport water. Systemic insecticides are carried in xylem tissue up the trunk to the branches and leaves in the canopy A few galleries have little effect on most trees. As EAB populations build and the tree becomes more infested, the injury becomes more severe. Canopies become thin because branches are too damaged to produce a full set of leaves. Large branches and even the trunk can be girdled and killed by the larval galleries.

Multi-year studies have shown that if more than 50 to 60% of the canopy has been killed by EAB, or if the canopy appears to be thin and is carrying less than half as much foliage as it should, it is probably too late to save the tree. The ability of trees to recover from low to moderate EAB injury can vary, depending on the extent of the damage and which control options are used. Studies have also shown that if the canopy of a tree is already declining when insecticide treatments begin, the condition of the tree may continue to deteriorate during the first year of treatment. If treatment is effective, the tree canopy will usually begin to improve in the second year of treatment. This lag in the reversal of canopy decline probably reflects the time needed for the tree to repair its vascular system after the density of EAB larvae has been reduced.

My ash tree looks fine but EAB has been detected in the vicinity of my property. Should I start treating my tree?

Detecting new EAB infestations and identifying ash trees that have only a few larvae is very difficult. Ash trees with a low density of EAB larvae usually have few or even no external symptoms or signs of infestation. In addition, scientists have learned that most EAB females lay their eggs on nearby trees, i.e. within 100 yards of the tree from which they emerged. A few female beetles, however, appear to disperse much further, anywhere from 0.5 miles to 2–3 miles. Therefore, if your property is within 30 miles of trees with noticeable EAB damage, then ash trees on your property are probably at risk. Signs of EAB damage include woodpecker holes or epicormic sprouts on the trunk or large branches, noticeably thin canopies or bark cracks above old larval galleries.

Treatment programs that begin too early waste money and result in unnecessary use of insecticide. However, treatment programs that begin too late will not be as effective. Trees must be healthy enough to carry the systemic insecticides to the leaves and branches in the canopy.

New EAB infestations continue to be discovered and existing EAB populations will build and spread over time. From 2002 to 2018, federal regulatory officials posted maps of quarantined states and counties on the www.emeraldashborer.info website. Federal regulatory surveys to detect EAB, however, have ended and state and local survey efforts vary. Therefore, maps of EAB detections may not adequately reflect the current distribution of EAB. City foresters, county extension offices or state departments of agriculture, forestry or natural resources may have information on the status of local EAB infestations. The www.emeraldashborer.info website provides links to specific information about EAB and regulations within individual states.

When is the best time to treat my trees?

As with any pest management effort, optimal timing is important to ensure insecticides provide effective EAB control. Your application of systemic insecticide should allow for uptake and distribution of the insecticide within the tree to ensure adult beetles and very young larvae encounter the toxin.

Two life stages of EAB are targeted by treatments: adult beetles and young larvae. Adult EAB feed on ash foliage throughout their life span and females must feed on leaves for at least 14 days before they begin laying eggs. This provides a window of opportunity to control the adults before any new eggs or larvae are produced. Beetle emergence usually begins sooner in the south than in northern areas. For example, the onset of adult beetle emergence begins in early May in southern Indiana and Ohio and in early June in central Michigan. Peak beetle emergence typically occurs two to three weeks after the first beetles exit the tree.

Ash trees on a street in Toledo in 2006 and 2009 before and after being impacted by EAB.

Regardless of location, emergence of adult EAB consistently begins at 450–550 growing degree days, based on a threshold of 50°F and a starting date of January 1. Beetles are most abundant at about 1,000 growing degree days. Cumulative growing degree days are tracked and posted on websites of many land grant universities as well as the NOAA website. First emergence of EAB also closely coincides with the period when black locust trees bloom. This phenological indicator is a reliable predictor of EAB emergence across a wide region, ranging from northern Michigan to Kentucky and Maryland.

Peak egg hatch and larval establishment occur between early June and early to mid August, depending on location and weather. As a general rule, young larvae are more susceptible to insecticides than are older larvae. Moreover, controlling young larvae prevents damage to the tree caused by older, larger larvae that feed in larger galleries and thus injure more area on the tree. Data from several university studies have shown that spring insecticide treatments are consistently more effective than the same treatments applied in fall.

Imidacloprid soil treatments generally require four to six weeks for uptake and distribution of the insecticide within the tree. In the upper Midwest, for example, applications should be made in mid-March to late April, depending on the region and spring weather. Treatments should be applied on the earlier side of these schedules in more southerly locations and later side in more northerly regions. To minimize effects on pollinators such as honeybees that might collect pollen from male ash trees (female trees do not produce nectar), soil-applied systemic insecticides can be applied just after ash trees flower. Ash flowering occurs for a few days in spring just before buds break leaves begin to emerge from buds.

Soil applications of dinotefuran can be applied 2–3 weeks later than imidacloprid. This compound, which is much more soluble than imidacloprid, is taken up and transported through the tree more rapidly. When dinotefuran is applied as a basal trunk spray, the insecticide moves into trees even faster. Basal trunk sprays of dinotefuran can be applied between late May and mid-June in much of the upper Midwest.

Optimal timing for trunk injections of emamectin benzoate occurs after trees have flowered and leaves are expanding. This period typically occurs from mid-May through mid June in much of the upper Midwest.

Sometimes a tree is not known to be infested until July or even August. In this situation, it is still possible to get some benefit from an insecticide treatment in the fall, but not as much as from a spring application. When emamectin benzoate is injected in September, for example, enough insecticide will move into the canopy the next spring to control leaf-feeding EAB adults and young larvae during the summer. However, control of EAB may not persist as long when emamectin benzoate is applied in the fall. Similarly, applying the 2× rate of imidacloprid in autumn, e.g., between early October and early November, will generally control EAB the following summer. A large field study showed, however, that over time, fall applications do not protect ash trees as effectively as spring applications of the same product.

How can I convince my community that action must be taken before it is too late to save the ash trees?

The first step is to educate your community about the threat posed by EAB and the value of the ash trees in the community. Members of some communities have acquired permission to mark ash trees with visual tags. This allows residents to clearly see the extent of the resource at risk. Other suggestions for organizing communities can be found in the "Neighbors Against Bad Bugs" fact sheet. You will want to cooperate with your city forester who may already have an inventory of street trees. An inventory will help identify where the ash trees are located, the size and species of the ash trees, and the proportion of the public forest at risk. Some cities use sophisticated inventory systems that even calculate the value of the services provided by the ash trees. In Milwaukee, WI, for example, the capacity of ash trees to filter storm water saves the city more than enough money to justify the cost of treating the trees. Other cities use similar programs to create visible tree tags that tally the dollar value of the services provided by each tree. The National Tree Benefits Calculator website provides information on calculating the value of trees for professional arborists and urban foresters. You may also wish to estimate or compare costs of different management responses to the EAB invasion over time. The EAB Cost Calculator website at Purdue University, for example, allows users to enter their own tree inventory, compare local costs of treatment options or tree removal, and print reports. Links to these websites are available at www.emeraldashborer.info or by using the website name in a google search.

I realize that I will have to protect my ash trees from EAB for several years. is it worth it?

Several factors can influence treatment decisions, including the condition, size and location of trees. Numerous studies have compared costs of removing urban ash trees versus costs of treating the same trees with emamectin benzoate. These studies assumed trees would need to be treated with emamectin benzoate every other year. Results consistently showed treatment costs are much lower than removal costs.

Recent work, however, shows emamectin benzoate applied in spring can provide effective EAB control for up to three years. New tools are also available now to substantially reduce the time it takes to inject a tree. Annualized costs of treating trees at 3 year intervals and more efficient applications obviously increase the ratio of benefits to costs even further.

Protecting ash trees in landscapes also ensures the trees continue to provide ecological services including storm water capture and shade. Economic value of these services increases the benefit to cost ratios even further. Of course, not all tree decisions are based on economics. Many people are sentimental about their trees. These intangible qualities are also important and warrant consideration when developing EAB management strategies.

It is worth noting that the density of an EAB population in a given area changes over time. Populations initially build slowly, but later increase rapidly as more trees become infested. As EAB populations reach peak densities, a high proportion of the untreated ash trees in the area will decline and die. This usually occurs over a 3–5 year period. Once untreated ash trees succumb, however, the local EAB population will decrease substantially. Several studies have found that EAB populations still persist, but at much lower densities on the few mature ash trees alive in the area. Young ash saplings in forests, right-of-ways or woodlots may be colonized by EAB and serve as a persistant source for infesting ash trees in the landscape. Suspension of treatments on protected ash trees after the untreated trees are dead may be a way to reduce protection costs. However, the decision to stop treatment or to extend the interval between treatments should include the initiation of a monitoring program to evaluate tree condition. This ensures that treatments can be resumed when local EAB activity increases well before trees sustain serious injury.

My customers want to know about the environmental impacts of systemic insecticides used to protect ash trees from EAB.

People often have questions about whether systemic insecticide products used to protect ash trees will harm the environment or other organisms such as woodpeckers and pollinators. A bulletin entitled "Frequently Asked Questions Regarding Potential Side Effects of Systemic Insecticides Used to Control Emerald Ash Borer" is available on the www.emeraldashborer.info website. The four page bulletin can be viewed on the website or downloaded and printed for distribution.

Insecticide Options for Controlling EAB

Insecticides that can effectively control EAB fall into four categories: (1) systemic insecticides that are applied as soil drenches or soil injections; (2) systemic insecticides applied as trunk injections; (3) systemic insecticides applied as lower trunk sprays; and (4) insecticides applied as cover sprays to the trunk, main branches, and (depending on the label), foliage.

Insecticide formulations and application methods that have been evaluated for control of EAB are listed in Table 1. Some are marketed for use by homeowners while several others are intended for use only by professional applicators. The "active ingredient" refers to the compound in the product that is actually toxic to the insect.

Formulations included in Table 1 have been evaluated in multiple field trials conducted by the authors and other university or government researchers. Inclusion of a product in Table 1 does not imply endorsement by the authors.

Strategies for the most effective use of these insecticide products are described below. It is important to note that pesticide labels and registrations change constantly and vary from state to state. It is the legal responsibility of the pesticide applicator to read, understand and follow all current label directions for the specific pesticide product used.

Using Insecticides to Control EAB

Soil-Applied Systemic Insecticides

Imidacloprid and dinotefuran are systemic insecticides that can be applied as soil drenches or soil injections. Both are sold under numerous brand names for use by professional applicators and homeowners. Soil applications can applied as a drench by mixing the product with water, then pouring the solution directly on the soil around the base of the trunk, or injecting the solution a few inches below ground at multiple locations near the base of the tree. The insecticide is taken up by the roots of the tree and then moves (translocates) up the tree to canopy branches and foliage.

Products designed for homeowners have some restrictions that do not apply to professional products. Homeowner products can be applied as a soil drench or as granules that are watered into the soil, but not as a soil injection. Homeowners are also restricted to making only one application per year.

Professionals can apply these products as a soil injection as well as a soil drench. Soil injections require specialized equipment, but offer the advantage of placing the insecticide below mulch or turf and directly into the root zone of the tree. This also can help to prevent runoff on slopes.

Injections should be made just deep enough to place the insecticide beneath the soil surface (2–4 inches). Soil injections should be made within 18 inches of the trunk.

Uptake is higher and the treatment more effective when the product is applied around the base of the trunk where the density of fine tree roots is highest. As you move away from the tree, large radial roots diverge like spokes on a wheel and fine root density decreases. Soil drenches offer the advantage of requiring no special equipment for application other than a bucket or watering can. However, imidacloprid can bind to surface layers of organic matter, such as mulch or leaf litter, which can reduce uptake by the tree. Before applying soil drenches, it is important to remove, rake or pull away any mulch or dead leaves so the insecticide solution is poured directly on the mineral soil.

Rates of soil applied insecticides needed to provide effective control may vary depending on the size of the tree and the intensity of pest pressure at the site. Some imidacloprid products available to professionals and homeowners can be applied at higher rates to large trees with trunk diameters (DBH) greater than 15 inches. Lower rates may be effective on smaller trees and when EAB populations are relatively low. Not all imidacloprid products can be applied at the higher rate so be sure to review the label when selecting a product.

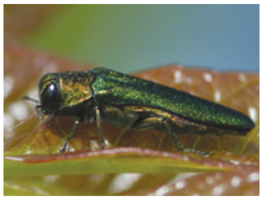
Treatment programs must also comply with the limits specified on the label regarding the maximum amount of an insecticide that can be applied per acre during a given year. This restricts the number of trees that can be treated in an area in a given year, especially when relatively high application rates are used or when large trees need treatment.

Soil applications should be made when the soil is moist but not saturated nor too dry. Insecticide uptake will be limited when soil is excessively dry. You may need to irrigate the soil surrounding the base of the tree before and possibly after the insecticide application if soils are dry. However, water-logged soil can result in poor uptake if the insecticide becomes excessively diluted and

TABLE 1. Insecticide options for professionals and homeowners for controlling EAB that have been tested in multiple university trials. Some products may not be labeled for use in all states. Inclusion of a product in this table does not imply that it is endorsed by the authors or that it has been consistently effective for EAB control. Additional products that have not been tested in multiple university trials may be available in your area. See text for details regarding effectiveness.

Insecticide Formulation	Active Ingredient	Application Method	Recommended Timing
Products Intended for Sale to Professional Applicators			
Merit® (75WP, 75WSP, 2F)	Imidacloprid	Soil injection or drench	Early to mid spring or mid fall
Safari™ (20 SG)	Dinotefuran	Soil injection or drench	Mid to late spring
Transtect™ (70WSP)	Dinotefuran	Soil injection or drench	Mid to late spring
Xylam® Liquid Systemic Insecticide	Dinotefuran	Soil injection or drench	Mid to late spring
Xytect™ (2F, 75WSP)	Imidacloprid	Soil injection or drench	Early to mid spring or mid fall
Azasol™	Azadirachtin	Trunk injection	Mid- to late spring after trees have leafed out
Arbormectin™	Emamectin benzoate	Trunk injection	Mid to late spring after trees have leafed out
Imicide®	Imidacloprid	Trunk injection	Mid to late spring after trees have leafed out
TREE-äge™	Emamectin benzoate	Trunk injection	Mid to late spring after trees have leafed out
TreeAzin®	Azadirachtin	Trunk injection	Mid to late spring after trees have leafed out
SafariTM (20 SG)	Dinotefuran	Systemic basal bark spray	Mid to late spring after trees have leafed out
Transtect (70 WSP)	Dinotefuran	Systemic basal bark spray	Mid to late spring after trees have leafed out
Zylam® Liquid Systemic Insecticide	Dinotefuran	Systemic basal bark spray	Mid to late spring after trees have leafed out
Astro®	Permethrin	Preventive trunk, branch, and foliage cover sprays	Two applications at 4-week intervals; first spray should occur at 450–550 degree days (50°F, Jan.1); Coincides with black locust blooming
Onyx™	Bifenthrin		
Tempo®	Cyfluthrin		
Sevin® SL	Carbaryl		
Products Intended for Sale to Homeowners			
Bayer Advanced™ Protect and Feed II	Clothianidin + Imidacloprid	Soil drench	Early to mid spring
Bayer Advanced™ Tree & Shrub Insect Control	Imidacloprid	Soil drench	Early to mid spring
Optrol™	Imidacloprid	Soil drench	Early to mid spring
Ortho Tree and Shrub Insect Control Ready to Use Granules®	Dinotefuran	Granules	Mid to late spring after trees have leafed out

may also result in puddles of insecticide that could wash away, potentially entering surface water or storm sewers. To further protect surface and ground water, soil applications should not be made to excessively sandy soils with low levels of organic matter that are prone to leaching, especially where the water table is shallow, or where there is risk of contaminating gutters, ditches, lakes, ponds, or other bodies of water.



EAB adults must feed on foliage before they become reproductively mature.

No soil applications should be made where roots of flowering plants can be visited by bees and other pollinators. This situation is most likely to occur when flowering plants are growing around the base of an ash tree. In these situations, the flowering plants should either be destroyed or insecticide should be applied via trunk injection to ensure the toxins will not be taken up by the flowering plants.

Trunk-injected Systemic Insecticides

Several systemic insecticide products can be injected directly into the base of the tree trunk, including formulations of azadirachtin, emamectin benzoate, and imidacloprid (see Table 1). An advantage of trunk injections is that they can be used on sites where soil treatments may not be practical, effective or appropriate, including trees growing on excessively wet, sandy, compacted or restricted soil environments. Trunk injections generally involve drilling through the bark and into the outer sapwood at the base of the tree. Drilling wounds could cause long-term damage, especially if treatments and applied annually in late spring. Recent studies of emamectin benzoate (TREE-äge™) injected using Arborjet plugs and imidacloprid applied with Mauget capsules®, however, showed ash trees rapidly recovered and began producing new wood over the wounds in late summer. Application methods that rely on high pressure injections of insecticide through needles inserted into small holes in the bark may damage the tree if the pressure causes the bark to bulge and separate from the cambium. This is most likely to occur in spring and can cause larger wounds that result from death of the vascular tissue at the point of separation.

Products applied as trunk injections are typically absorbed and transported within the tree more quickly than soil applications. Rate of transport within trees varies among products. Imidacloprid moves more slowly than emamectin benzoate while azidirachtin and dinotefuran products move relatively rapidly. Imidacloprid usually takes 2–3 weeks to reach the canopy while other products reach the canopy within a week. Optimal timing of trunk injections occurs after trees have leafed out in spring but before EAB adults have started to lay eggs. This timing generally between mid-May and mid-June in the upper Midwest. Uptake of trunk-injected insecticides will be most efficient when trees are actively transpiring. Best results are usually obtained by injecting trees in the morning when soil is moist but not saturated. Uptake may be slowed by hot afternoon temperatures as well as dry soil conditions. Irrigating trees during droughty conditions will help with insecticide uptake and translocation within the tree.

Noninvasive, Systemic Basal Trunk Sprays

Dinotefuran is labeled for application as a noninvasive, systemic trunk spray for EAB control. It belongs to the same chemical class as imidacloprid (neonicotinoids) but is much more water soluble and moves more readily through plants. The formulated insecticide is sprayed on the lower five to six feet of the trunk using a common garden sprayer and low pressure. The insecticide penetrates the bark and is transported systemically throughout the tree. The basal trunk spray offers the advantage of being quick and easy to apply and requires no special equipment other than a garden sprayer. This application technique does not wound the tree, and when applied correctly, little insecticide enters the soil. Sprayers must be calibrated to ensure the appropriate amount of the formulated product is applied to each tree.

Dinotefuran can be mixed with surfactants that may facilitate its movement into the tree, particularly on large trees with thick bark. However, in field trials, adding a surfactant did not consistently increase the amount of insecticide recovered from leaves of treated trees or improve effectiveness of the application.

Protective Cover Sprays

Although control is possible with protective cover sprays, it is not recommended because of problems with spray drift, coverage and effects on nontarget species. Cover sprays applied to the trunk, branches and foliage can kill adult EAB beetles as they feed on ash leaves, and newly hatched larvae as they chew through the bark. Thorough coverage is essential for this to work. Products that have been evaluated include some specific formulations of permethrin, bifenthrin, cyfluthrin and carbaryl (see Table 1). Be careful to read the label because some products can be applied to bark but not to foliage.

Protective cover sprays are designed to control EAB adults and might control some of the very young larvae that hatch from eggs laid after pesticide has been applied. Sprays will have no effect on larvae feeding under the bark. Cover sprays should be timed to occur when most adult beetles have emerged and are feeding on ash leaves. For best results, consider two applications, one at 500 DD_{50} (as black locust approaches full bloom) and a second spray four weeks later.

How Effective Are Insecticides for Control of EAB?

Extensive testing of insecticides for control of EAB has been conducted by researchers at Michigan State University (MSU) and The Ohio State University (OSU) (Purdue University and Morton Arboretum). The following sections summarize key results of these trials.

Healthy ash trees that have been protected with imidacloprid soil drenches in 2009 growing next to untreated ash trees injured by EAB. The same street in 2011 following six consecutive years of treatments during a peak EAB outbreak. Untreated trees declined and were removed.

Soil-Applied Systemic Insecticides

Efficacy of soil-applied systemic insecticides for controlling EAB has been inconsistent. In some OSU and MSU trials, EAB control was excellent, while others yielded poor results. Application protocols and conditions of the trials have varied considerably, making it difficult to reach firm conclusions about sources of variation in efficacy.

Some imidacloprid formulations can be applied to trees with a trunk diameter

EAB larvae damage the vascular system of the tree as they feed, which interferes with movement of systemic insecticides in the tree.

greater than 15 inches at a rate that is twice as high (2× rate) as the rate used for smaller trees (1× rate). In an OSU study in Toledo conducted from 2006–2014, imidacloprid soil drenches effectively protected ash trees ranging from 15–22 inches in diameter when applied at the 1× rate in spring, or at the 2× rate when applied in either the spring or fall. These treatments were effective even during years of peak pest pressure when all of the untreated trees died. Trees treated in fall with the 1× rate, however, declined and had to be removed.

In another OSU multi-year trial with trees up to 22 inches DBH, dinotefuran soil applications, as well as basal trunk sprays (see below) were effective when applied at the highest labeled rate. However, lower rates were less effective. Soil applications of imidacloprid at a lower rate (the rate recommended for turf insects) did not protect ash trees.

Results from several studies in MI, OH, IL, and IN since then have similarly indicated that high rates of imidacloprid must be applied to protect larger trees. Adding either clothianidin or fertilizer to the formulation of imidacloprid products did not provide any additional protection from EAB.

Researchers have found that soil drenches and injections made at the base of the trunk result in more effective uptake than applications made in grid or circular patterns under the canopy away from the trunk.

Trunk-injected Systemic Insecticides

Emamectin benzoate • In several intensive studies conducted by MSU and OSU researchers at MSU, OSU, Morton Arboretum and Purdue, a single injection of emamectin benzoate (TREE-äge™) in mid-May or early June provided excellent control of EAB for up to three years, even during years of peak EAB densities. For example, in a highly-replicated study conducted on trees ranging in size from 5 to 21-inch DBH at three sites in Michigan, untreated trees had an average of 68 to 132 EAB larvae per m^2 of bark surface, which represents very high pest pressure. In contrast, trees treated with low rates of emamectin benzoate (0.1–0.2 g ai or 2.5 ml per inch DBH) had, on average, only 0.2 larvae per m^2, a reduction of >99 percent. When additional trees were felled and debarked two years after the emamectin benzoate injection, there were still virtually no larvae in the treated trees, while adjacent, untreated trees at the same sites had hundreds of larvae.

In two Ohio studies with street trees ranging in size from 15- to 25-inch DBH, a single application of emamectin benzoate provided excellent control for two years, even at the lowest rate. There was no sign of canopy decline in treated trees and very few emergence holes, while the canopies of adjacent, untreated trees exhibited severe decline and extremely high numbers of emergence holes. In another trial, large trees, ranging from 32 to 53 inches DBH, were treated in alternate years with emamectin benzoate at medium- low or medium-high rates. Canopies of all treated trees remained healthy six years later (after three treatment cycles) despite high pest pressure and numerous declining (untreated) trees in the immediate vicinity.

In a six year Purdue study, trees with DBH ranging from 28 to 62 inches were effectively protected from EAB when injected in June with a medium rate (0.2 g ai or 5 ml per DBH inch) of emamectin benzoate once every three years. By the end of the study in 2018, untreated trees were dead or dying. Trees treated in June had less than 15% canopy thinning. When treatment was delayed until September, however, trees sustained unacceptable levels of canopy thinning by 2018.

Two of the most recent studies have shown that even when TREE-äge™ is applied at the lowest rate on the label (0.1 g ai or 2.5 ml per DBH inch), trees are protected from EAB for three years. A six year MSU study quantified EAB larval densities on trees treated annually, at 2 year intervals or at 3 year intervals with a low (2.5 ml per DBH inch) or medium (5 ml per DBH inch) rate of TREE-age, dinotefuran basal trunk sprays or imidacloprid applied with Mauget capsules. Treated and untreated control trees were felled and debarked to assess efficacy. Results showed that both rates of TREE-äge provided nearly complete EAB control for three years post-treatment. Biennial and annual TREE-äge injections, as well as annual basal trunk sprays of dinotefuran provided similarly high levels of control, while imidacloprid injections were less effective, even when applied annually. In other trials with side-by-side comparisons of insecticide products, emamectin benzoate has been consistently more effective than other systemic insecticides.

Between 2008 and 2014, a study with 205 green ash trees ranging from 12 to 15 inches DBH was conducted outside of Chicago by a researcher at the Morton Arboretum. By 2014, untreated trees had lost 93% of their canopy. Trees treated with of 2.6 gm ai/ inch of emamectin benzoate (6 ml per DBH inch) every two years had less than 25% canopy thinning in 2014. In contrast, trees treated with annually with soil injections of neonicotinoids in the spring or fall at 1× or 2× rates had lost > 50% of their canopies by 2014.

Healthy ash trees protected with emamectin benzoate trunk injections behind an untreated, declining tree.

Azadirachtin • Results from a two-year study in Michigan replicated at three sites showed azadirachtin products affect EAB differently than other insecticide products. In this study, adult EAB beetles fed for six days on leaves from trees treated with a high rate of azadirachtin (TreeAzin®), then fed on leaves from untreated trees for the remainder of their life span. In contrast to trees treated with either emamectin benzoate (trunk injection) or dinotefuran (basal trunk spray), leaves from the azadirachtin trees were not acutely toxic to adult beetles. However, azadirachtin reduced the ability of mature female beetles to produce viable eggs that successfully hatched. Young females, conversely, appeared to recover and were able to reproduce normally.

When the trees in this study were felled and debarked after two years of exposure to EAB, it was apparent that numerous EAB larvae had begun feeding on trees treated with TreeAzin. Most of the larvae died while still young and small. Very few live larvae were present on the trees treated in both years with TreeAzin. When trees were treated only the first year but not the second year, density of live larvae was 75–80% lower than on untreated control trees. Results from this study suggest that in most years, TreeAzin will effectively protect ash trees for two years, but when EAB densi- ties are high, annual applications are necessary.

Imidacloprid • Trunk injections with imidacloprid products have provided varying degrees of EAB control. In an MSU study, larval density in trees treated annually with Imicide® injections were reduced by 60 to 96 percent, compared to untreated controls.

There was no apparent relationship between efficacy and trunk diameter or infestation pressure. In another MSU trial, imidacloprid trunk injections made in late May were more effective than those made in mid-July, and IMA-jet® injections provided higher levels of control than did Imicide®, probably because the IMA-jet® label calls for a greater amount of active ingredient to be applied on large trees. In an OSU study, IMA-jet® provided excellent control of EAB on 15- to 25-inch trees under high pest pressure when trees were injected annually. However, trees that were injected every other year were not consistently protected.

In a discouraging study conducted in Michigan, ash trees continued to decline from one year to the next despite being injected in both years with either Bidrin (Inject-A-Cide B®) or imidacloprid. The imidacloprid treat- ments consisted of two consecutive years of Imicide® (10% imidacloprid) applied using Mauget® micro-injection capsules (3 ml), or an experimental 12% formulation of imidacloprid in the first year followed by Pointer™ (5% imidacloprid) in the second year with both applied using the Wedgle™ Direct-Inject™ System. All three treatment regimens suppressed EAB infestation levels in both years, with Imicide® generally providing best control under high pest pressure in both small (six-inch DBH) and larger (16-inch DBH) caliper trees. However, larval density increased in treated and untreated trees from one year to the next. Furthermore, canopy dieback increased by at least 67 percent in all treated trees (although this was still less than the amount of dieback observed in untreated trees). Even consecutive years of these treatments only slowed ash decline under severe pest pressure.

In a head-to-head comparison of products conducted by OSU researchers, emamectin benzoate trunk injections (0.4 g a.i. / inch DBH applied during the first year in May) and imidacloprid soil drenches (applied in both years in May at the highest labeled rates) provided effective control of EAB. In contrast, trees treated with Pointer™ (5% imidacloprid applied in both years in May at the highest labeled rate) and the untreated trees declined substantially over the two-year study period. In another MSU study, ACECAP® trunk implants (active ingredient is acephate) did not adequately protect trees > 15-inch DBH under high pest pressure.

Noninvasive Systemic Basal Trunk Sprays

Studies to date indicate that the effectiveness of dinotefuran basal trunk sprays are similar to soil applications of dinotefuran or imidacloprid. MSU and OSU studies have evaluated residues in leaves from trees treated with the basal trunk spray. Results showed that the dinotefuran effectively moved into the trees and was translocated to the canopy at rates similar to those of other trunk-injected insecticides, and faster than soil-applied neonicotinoid products. As with imidacloprid treatments, control of EAB with dinotefuran has been variable in research trials. Several MSU studies ranging from two to six years have shown annual dinotefuran basal trunk sprays effectively protect ash trees and significantly reduce EAB larval densities compared to the heavily infested untreated trees. As with dinotefuran and imidacloprid soil applications, the basal trunk treatment was effective for only one year and would have to be applied annually.

In a five-year OSU study with trees up to 22 inches DBH, dinotefuran basal bark sprays provided effective protection when applied at the highest labeled rate (average of less than 5% canopy decline compared with nearly 80% average canopy decline for untreated trees). A lower rate was less effective (almost 20% average canopy decline).

Protective Cover Sprays

MSU studies showed that a cover spray of Onyx™, Tempo® or Sevin® SL provided good control of EAB, especially when the insecticides were applied in late May and again in early July. Acephate sprays were less effective. BotaniGard® (Beauvaria bassiana) was also ineffective under high pest pressure. Astro® (permethrin) was not evaluated against

EAB in these tests, but has been effective for controlling other species of wood borers and bark beetles.

In another MSU study, spraying Tempo® just on the foliage and upper branches or spraying the entire tree were more effective than simply spraying just the trunk and large branches. This suggests that cover sprays may be especially effective for controlling EAB adults as they feed on leaves in the canopy. A single, well-timed spray was also found to provide good control of EAB, although two sprays may provide extra assurance, given the long period of adult EAB activity.

It should be noted that spraying large trees is likely to result in a considerable amount of insecticide drift, even when conditions are ideal. Drift and potential effects of insecticides on non-target organisms should be considered when selecting options for EAB control.

Key Points and Summary Recommendations

- Insecticides can effectively and consistently protect ash trees, including very large trees, from EAB, even under intense pest pressure.
- Drought stress inhibits uptake and transport of systemic insecticides. Supplemental irrigation will be needed during dry periods.
- Unnecessary insecticide applications waste money. However, survey activities to detect or monitor EAB infestations vary considerably among and within states. In addition, EAB infestations are very difficult to detect when populations are low. Nearly all EAB infestations have been at least four to six years old before they were detected. If ash trees with obvious signs of EAB infestation are within 30 miles, you should consider beginning treatment. It is important to stay aware of the status of EAB in your location. Check the www.emeraldashborer.info website for current maps of known EAB distribution AND links to other websites with information specific to your state, county or municipality.
- Trees that are already infested and showing signs of canopy decline when treatments are initiated sometimes continue to decline the first year after treatment, then begin to improve the second year, as the trees recover. Effectiveness of products varies considerably, however, depending on the product applied, the extent of injury already sustained by the tree and the pest pressure. Trees with lower levels of canopy decline may not recover despite treatment.
- Emamectin benzoate has consistently provided highly effective EAB control for two and even three years with a single application. This level of efficacy has been consistently recorded even in sites where large and very large trees were under intense pest pressure. This insecticide also provided greater EAB control than other products in side-by-side studies.
- Trunk injections of azadirachtin affect EAB differently than other systemic insecticides. Results from a recent study indicate azadirachtin should provide effective protection for one to two years, depending on EAB pressure.
- Basal trunk sprays with dinotefuran applied annually have effectively protected ash trees in several studies. It is important to calibrate sprayers to ensure the proper rate of the formulated product is applied.
- Soil applications of imidacloprid and dinotefuran yielded mixed results. In some studies, soil drenches or soil injections of imidacloprid effectively protected trees while in other studies, they failed. Yet these products remain the only option for many homeowners who choose not to hire a professional. Individuals who want to try this option should apply these products at the highest labeled rate. Soil drenches should be applied at the base of the trunk where fine roots are concentrated. Soil injections should be no more than 2–4 inches deep, to avoid placing the insecticide beneath feeder roots of the tree. Users must comply with all restrictions on application frequency and the amount of insecticide that can be applied per acre per year.

The Cooperative Emerald Ash Borer Program

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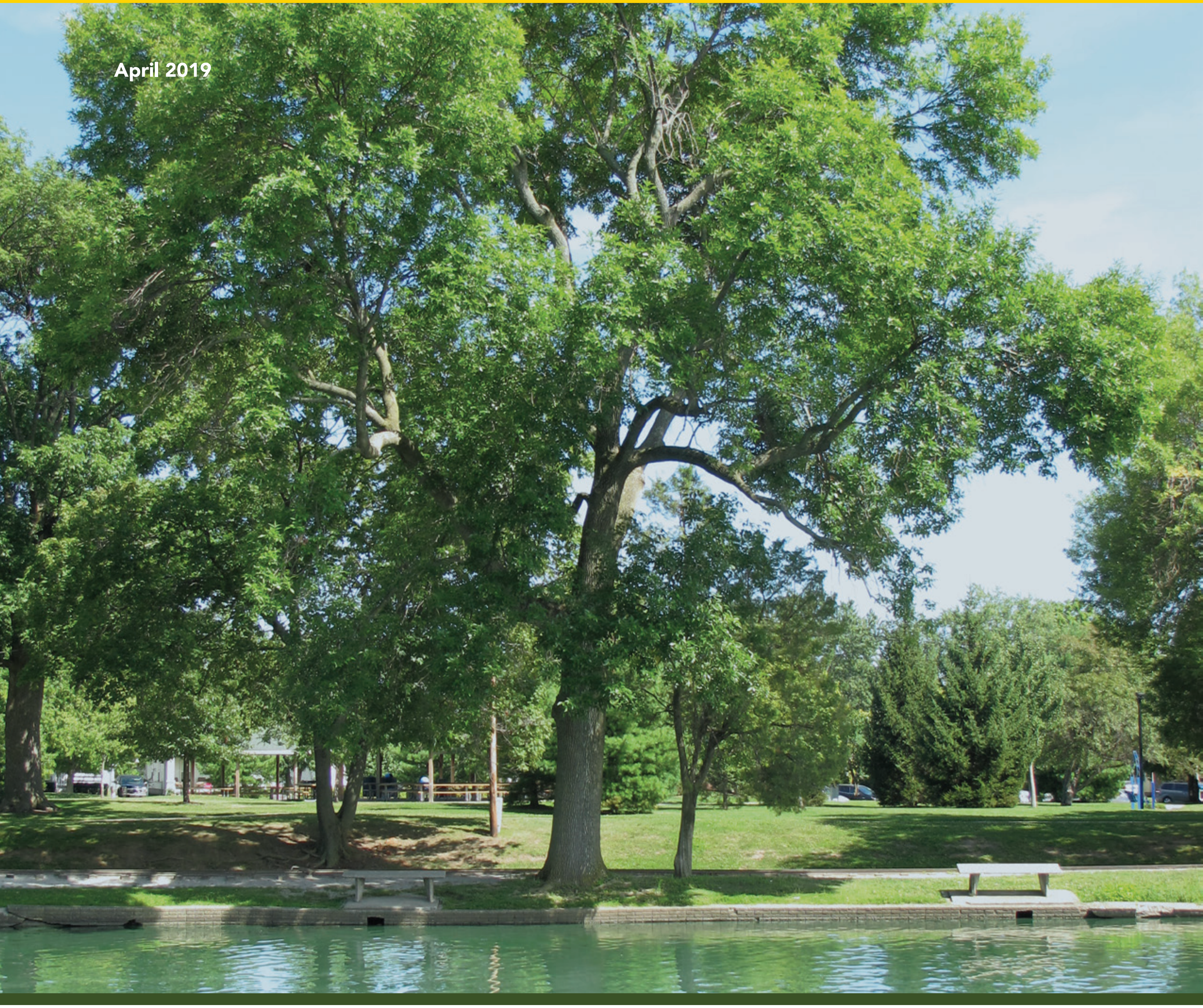

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